OETD
Office of
Electric Transmission & Distribution
Electric Distribution Transformation Program

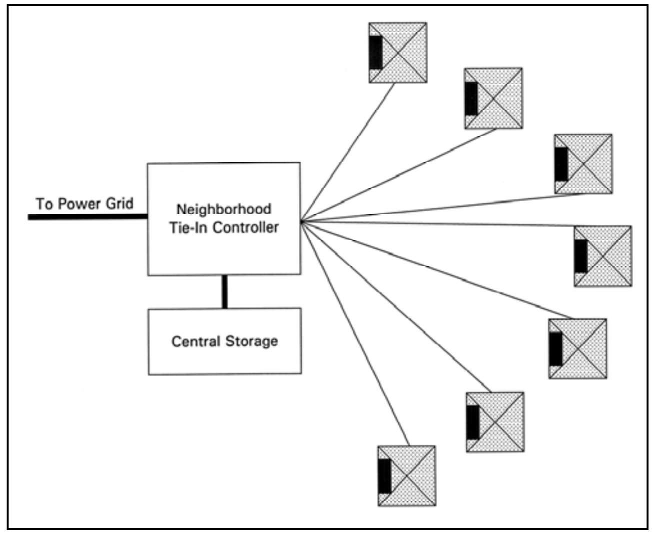
Orion Engineering Corp.

Intelligent Solutions for Distributed Power Technology

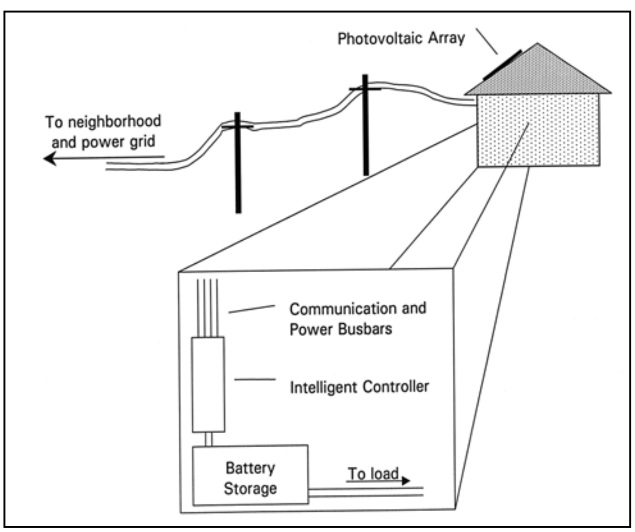
Overview

The purpose of this research is to demonstrate a neural-network control system for managing small distributed generation (DG). Orion Engineering Corp. has developed a system called the Distributed Energy Neural Network Integration System (DENNIS®). This system combines discretionary control for individual distributed generators with a networked neighborhood hub control module that aggregates the small generators into a virtual single, large generator capable of selling power to the grid. The small distributed generators include biomass-based generators, fuel cells, combustion turbines, micro-turbines, wind turbines, photovoltaic systems, and storage.

When completed, DENNIS will maximize the return on investment for each installation by monitoring utility demand and other parameters to predict and act on future opportunities to buy and sell power. This distributed control architecture provides choice to individual generators. They produce electricity and can optimize its use by managing when to consume it or sell it to the grid with the benefits of aggregation.



The DENNIS® Neighborhood Tie-In Controller subsystem aggregates power from several small distributed generators for dispatch to the grid



Schematic of an individual controller and a small distributed generator

Results

The DENNIS System

Orion's DENNIS performs multiple functions, including measuring the real-time market pricing for electricity, and is linked to information such as individual demand profiles, the state of storage and rate of discharge of batteries, weather conditions, and available power from on-site generation sources. Based on these parameters, the DENNIS controller chooses an optimum dispatch schedule for attached DG systems. Information about the availability of excess generation is fed to a control hub or Neighborhood Tie-In Controller (NTIC). The NTIC handles all transactions with outside entities, including the sale of excess electricity to utilities, for the aggregated DG systems. Because the NTIC is the nexus of an aggregated generation capacity that could be as large as several hundred kilowatts, it represents an appropriate block of energy for bulk trading. Therefore, the NTIC provides the means for small DG power producers to optimize the sale of their electricity to the grid.

DENNIS uses real-time pricing linked directly to individual demand profiles to optimize power generation and power pricing. Real-time pricing and local discretionary control eliminate the need for complicated central control and monitoring methodologies. Further, the DENNIS control action at the individual level, spread across all controllers in the DENNIS territory, enables the aggregated community to present a flat load profile to the incumbent utility. The result is an entirely new aggregation model supporting a variety of utility contracts.

Orion's preliminary benchmarking demonstrates that DENNIS outperforms net metering and avoided cost in compensating residential DG customers for their power. For example, modeled results indicate DENNIS achieves daily electricity savings of 90%–125% for photovoltaic installations. This is 35% more savings than net metering programs and 75% more than avoided-cost programs. For a hydrocarbon-based installation managed by DENNIS, the savings are 50%, which is 15% better than net metering (if avoided cost does generate any savings).

How It Works

The foundation of the system is a neural network that maps a wide range of inputs—including market prices, power demand, weather conditions, and DG power availability—to a set of control actions. These dictate the flow of energy from generation and other energy sources to the household load, storage, and the grid.

The DENNIS charge/discharge controllers apply the information provided by the neural network subsystem to optimally dispatch the local DG. The entire system undergoes supervised training in a closed-loop system to continually refine its performance. The training process is managed by a control law generator, which uses linear programming to seek control solutions that maximize the potential profit or minimize the cost to the individual small business or household, depending on whether the entity is a net seller or purchaser of electricity.

Recently, Orion put the DENNIS architecture to test by having it classify various types of days based on primitive weather inputs. Weather is a crucial parameter in DENNIS discretionary control because it indicates a user's power requirements for heating and cooling as well as the availability of power from renewable DG resources. Using a very limited data set (one month of weather data), the neural network achieved 80% accuracy in classifying the day type based on inputs of insolation, temperature, barometric pressure, and time of day. With these simple measurements, the program distinguished between rainy, hazy/rainy, and sunny days.

By predicting trends in weather, load, and market price, the DENNIS system can take future demand and generation potential into account when deciding on a current control strategy. DENNIS can store energy in advance of anticipated DG energy production shortfalls and apply real-time grid pricing to avoid a power purchase or make an opportune sale of DG power. For example, DENNIS may delay selling battery-stored energy to the grid until it is most profitable even though current conditions also provide positive gains. DENNIS does not seek short-term profits at the cost of long-term gains.

What's Next

Orion is now working to integrate and test the DENNIS hardware and software and evaluate how best to make the product available. Controllers are being configured and installed at multiple locations. These will be used to test performance and signaling at multiple, diverse locations, analyze data from diverse sites, develop a central controller for large blocks of users, and begin integration with the utility—in short, to evaluate the performance of DENNIS under actual operating conditions and prepare it for larger-scale implementation.

Publications

Regan, T.; Sinnock, H.; Davis, A. "Distributed Energy Neural Network Integration System: Year One Final Report." NREL/SR-560-34216. June 2003.

Publications are available on the NREL publications database, http://www.nrel.gov/publications/.

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